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13. ABSTRACT ***(Maximum 200 Words)*** In February 1997, the Office of the Chief of Naval Operations identified the need for quick reaction Tactical Tomahawk mission planning onboard Tomahawk Firing Units (FRU's). Other significant capabilities identified for "next generation Tomahawk" included the ability to redirect an in-flight missile, loiter a missile to allow quick reaction re-planning and provide Battle Damage Indication and Imagery to Tomahawk Command and Control stations. These capabilities have been successfully brought forward through the development of the Tactical Tomahawk Weapons Control System (TTWCS). Along with these new capabilities, TTWCS inherits legacy functionality from its predecessor, ATWCS, including shared Advanced Tactical Display Consoles (ATDC) with the Naval Fires Control System (NFCS). While these capabilities enable the tactical employment of Tomahawk Land Attack Missiles (TLAM), they also place new training and workload challenges on the operator. These include the unnecessary burdens placed on operators forced to toggle between non-integrated NFCS and TTWCS displays.
This paper provides an overview of the evolutionary HCI development approach undertaken by the Cruise Missile Weapons Control Systems Program Office (PMA-282). Specific focus is placed on design process changes from TTWCS IOC to Version 5 and how those changes support User Centered Design. It will also discuss further reaching activities that are essential to achieving and Integrated Land Attack Presentation Layer.

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Distributed Weapons: Sea Strike Human Systems Integration in Tactical Tomahawk Weapons Control System Development

ABSTRACT

In February 1997, the Office of the Chief of Naval Operations identified the need for quick reaction Tactical Tomahawk mission planning onboard Tomahawk Firing Units (FRU's). Other significant capabilities identified for "next generation Tomahawk" included the ability to redirect an in-flight missile, loiter a missile to allow quick reaction re-planning and provide Battle Damage Indication and Imagery to Tomahawk Command and Control stations. These capabilities have been successfully brought forward through the development of the Tactical Tomahawk Weapons System (TTWS). Along with new capabilities, the TTWS Weapons Control Segment (TTWCS) inherits legacy functionality from its predecessor, the Advance Tomahawk Weapons Control System (ATWCS), including shared Advanced Tactical Display Consoles (ATDC) with the Naval Fires Control System (NFCS). While these capabilities enable the tactical employment of Tomahawk Land Attack Missiles (TLAM), they also place new training and workload challenges on the operator. These challenges are exasperated by unnecessary burdens placed on operators forced to toggle between non-integrated NFCS and TTWCS displays.

Research conducted at the University of Virginia has concluded that cognitive limitations of a single operator will inhibit the Launch Platform from monitoring and controlling all own-ship launched missiles unless dramatic gains in Strike team performance are achieved through the elimination of stove-piped data sources and disjointed displays. Integration of information and displays is essential to satisfy demands of shorter timelines associated with Land Attack Warfare and represents the core of the Tactical Tomahawk Weapons Control System Roadmap. The emphasis to place the operator at the center of system development is compliant withOPNAV Guidance: "...our ability to effectively and successfully employ Land-Attack Warfare systems will directly reflect our commitment to Human-Centered Design, Human Systems Integration, and Optimal Manning."

PMA-282 has converted these words into action by mandating the use of Task Centered Design principles in all facets of Weapons Control System development. This has started by placing the highest emphasis on User Work Flow Analysis and adherence to these workflows throughout the development and test cycles for future Tomahawk upgrades. A key development has been the incorporation of a "Task Manager" as the first step toward a Task-Centered Design that has already been shown to significantly reduce cognitive workload, error rates, and task completion times. Since operator productivity and effectiveness is central to all future development, TTWCS Version 5 (v5) will be the first Tomahawk baseline that applies human-performance, hardware and software measures, on an equal basis.

The Program Office has also placed great emphasis on achieving common look and feel displays across multiple Land Attack Systems. As a first step, the TTWCS Program has developed a HCI Style Guide that will be enforced for TTWCS v5 designs. Additionally, the program intends to capitalize on Office Of Naval Research (ONR) funded research that explores architectural alternatives to allow separation of all TTWCS HCI from the underlying Weapon Control System

applications. Separation of the HCI from weapons system applications is fundamental to designing human interfaces around complete warfare tasks rather than individual operator functions. In doing so, the operator's view is expanded from looking through a "soda straw" to a "knowledge wall."

This paper provides an overview of the evolutionary HCI development approach undertaken by the Cruise Missile Weapons Control Systems Program Office (PMA-282). Specific focus is placed on design process changes from TTWCS IOC to Version 5 and how those changes support User Centered Design. It will also discuss further reaching activities that are essential to achieving and Integrated Land Attack Presentation Layer.

INTRODUCTION

Tactical Tomahawk Description

The Tactical Tomahawk Weapons Control System represents the latest generation of Tomahawk Weapons Control. It builds on the capabilities of its predecessor, Advance Tomahawk Weapons Control System (ATWCS), by offering new capabilities geared toward *tactical employment* of the Tomahawk Cruise Missile. Its origin can be traced to the Tomahawk Improvement Program that identified the need for quick reaction Tomahawk Mission Planning onboard Launch platforms. Other significant capabilities included the ability *to redirect an in-flight missile, loiter a missile* to allow quick reaction replanning and provide Battle Damage Indication and Imagery to Tomahawk Command and Control stations.

Aside from TTWCS, the Tactical Tomahawk Weapons System (TTWS) includes a Command and Control Segment (TC2S) and the Tactical Tomahawk Missile. Figure (1) provides a graphical representation of Tactical Tomahawk Weapon System capabilities and relationships. Details of these capabilities are provided in following sections.

Legacy Features

In addition to its new features, TTWCS retains the planning and preparation functions carried forward from ATWCS. These functions include:

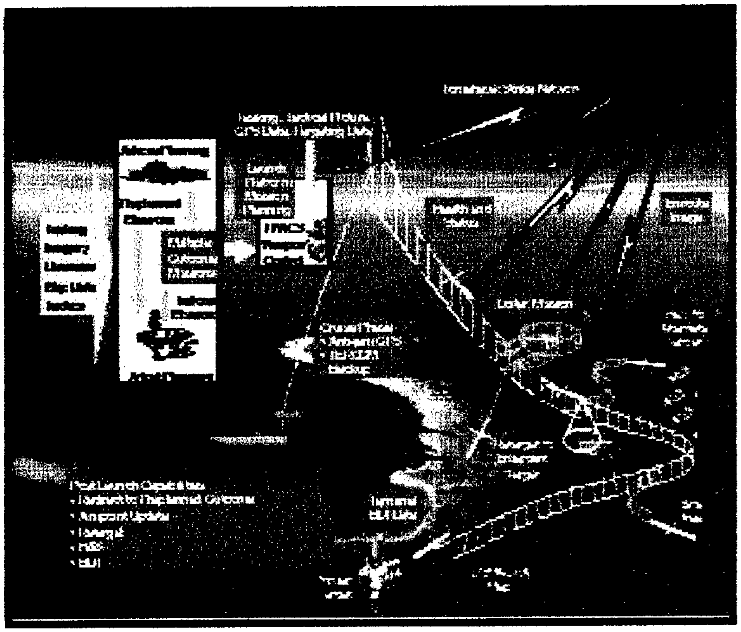


FIGURE 1 - TACTICAL TOMAHAWK WEAPONS CONTROL SEGMENTS

1. Tasking validation- TTWCS processes strike planning and execution tasking sent from Tomahawk Command and Control Nodes. This tasking is in the form of a Strike Packages generated and sent from a Mission Distribution System hosted on a Windows NT PC (PC-MDS). .
2. Engagement Planning- Planning the Over the Water Route for the missile. These flight plans are developed and deconflicted to conform to guidance set forth by the Launch Area Coordinator (LAC).
3. Launch Control- Includes missile initialization and preparation. This sequence contains the necessary steps for loading the missile with flight software, navigation data, and mission data prior to missile launch.

New Features

The two prominent features that distinguished TTWCS from ATWCS are its ability to plan Tomahawk Missions on Firing Units and its ability to control Tomahawk Missiles in flight.

Launch Platform Mission Planning (LPMP)

TTWCS adds Launch Platform Mission Planning allowing firing platforms the ability

fully plan Tomahawk missions (a role previously performed exclusively at shore sites and Carrier Based Afloat Planning Centers (APS)). LPMP produces mission routes which considers the geographic features of the flight path, anti-air threats to the missile and deconfliction areas. Since TTWCS retains the ability to plan over water missiles routes, the addition of a mission planning capability on Firing Units now allow ships to plan the complete mission route from the ship to the target. This removes the exclusive dependency on Satellite Communication circuits for delivery of Tomahawk Missions to Firing Units. By removing this time lag, TTWCS ships can now fully plan and execute missions within previously unattainable timelines and serves as a viable option for Tactical Strikes.

Post Launch Control

New to Tactical Tomahawk is the ability to communicate with an inflight TACTOM missile. This communication links the missile to either TTWCS or PCMDS using 5 kHz UHF DAMA. These circuits connect the Tomahawk Strike Network and are used to exchange Missile Health and Status Messages Battle Damage Indication (BDI) and Imagery (BDII), or redirect in-flight missiles to alternate targets.

Interface with Mission Planning Systems

TTWS includes the Tomahawk Command and Control System (TC2S) that supports the operational commanders in the planning, tasking, and employment of TLAM. TC2S is not specific to Tactical Tomahawk; rather it also supports the previous Block III variant missile.

Shore and Carrier Based Components

TC2S is made up of individual systems deployed at Shore Based Planning Sites and Carrier Based Afloat Planning Centers (APS). Shore Based and Carrier Deployed Planning Centers are equipped with the following components:

1. Tomahawk Planning System (TPS) – used to prepare and maintain Tomahawk routes as part of Tomahawk mission planning.
2. Precision Targeting Workstation (PTW)- used to screen imagery contained within Electronic Targeting Folders.
3. Digital Imagery Workstation (DIWS)- generates imagery-based products including targets, Digital maps, etc. to support Tomahawk route planning.

TC2S on Firing Units

The TC2S component that serves as the interface between the Shore and Carrier Based Mission Planning Centers and Tomahawk capable Ships and Submarines is the Mission Distribution System (MDS). Since Tomahawk Missions have traditionally been planned off the ship, MDS served as the system providing distribution and accountability of Tomahawk Missions between the Planning Centers and the Firing Units. With Tactical Tomahawk, this functionality has been retained, and has been rehosted on a Windows Based PC. This PC version also brings additional capability that is common to both PC-MDS and TTWCS. Among these new features are the ability to plan and produce Strike Packages for dissemination to Tomahawk Firing Units as well monitoring and controlling Tomahawk Missiles in flight.

Naval Fires Control System

The Naval Fires Control System (NFCS) was born out of the need to provide the necessary functionality to execute Extended Range Guided and conventional target engagements in a timely, accurate, and efficient manner. Additionally, it was identified to provide improvements over existing Naval Fires Support procedures that are labor intensive and inefficient.

It provides for coordination and deconfliction of naval fires in the area of operations by incorporating available Airspace Control Orders (ACO), Air Tasking Order (ATO) and Fires Support Control Measures (FSCM) in a 3D geometry of airspace limitations and restrictions versus time. NFCS processes the ballistic geometry of Surface launch projectiles, check it against applicable airspace, and alert the NFCS operator for possible conflicts.

NFCS is fielded on ATWCS and TTWCS Cruisers and Destroyers. NFCS operations are performed by Tomahawk operators using a common display shared by both systems. The use of a common display console is achieved through a Video Switching Architecture that allocates individual ATDC's to exclusive NFCS or Tomahawk Operations. This arrangement forces a single operator to toggle between nonintegrated HCI, each with its own symbology and behavior.

External Interfaces

TTWCS interfaces with numerous on-board and off-board systems, external to the TTWS, which are necessary for preparing and launching missiles. Figure (2) and Table (1) visually depicts and summarizes these interfaces.

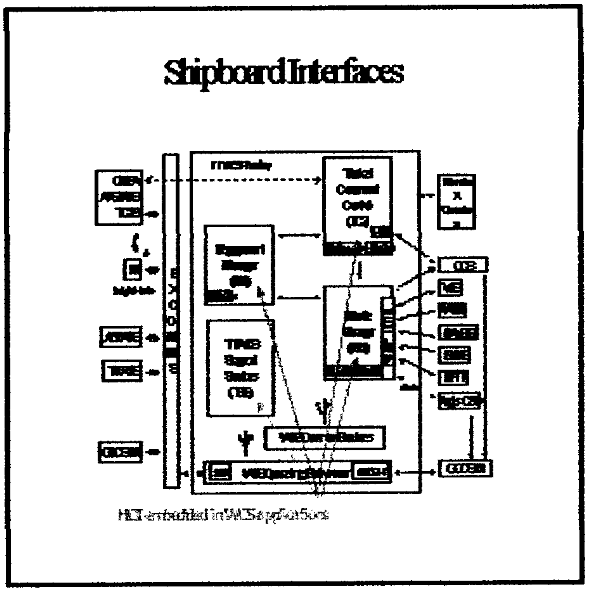
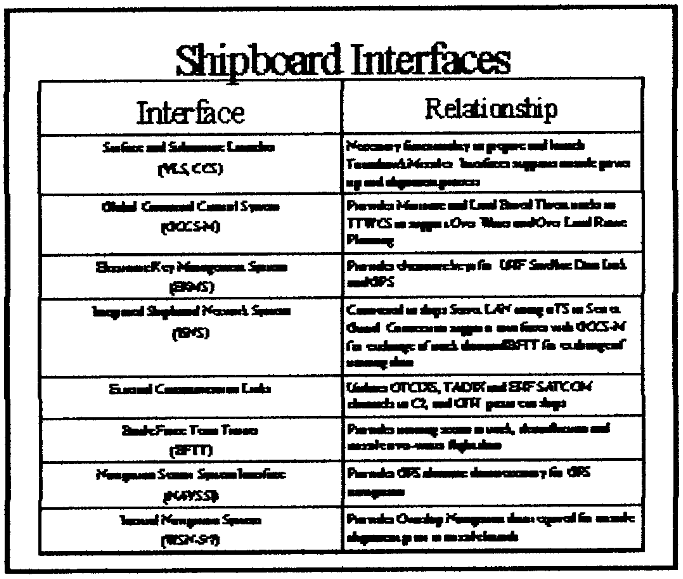


FIGURE 2-SHIPBOARD INTERFACES



Shipboard Interfaces

Interface	Relationship
[illegible] (VLS, CCS)	[illegible]
[illegible] (GCCS-M)	[illegible]
[illegible] (EKMS)	[illegible]
[illegible] (ISNS)	[illegible]
[illegible]	[illegible] OTCIXS, TADIX [illegible] SATCOM [illegible]
[illegible] (BFTT)	[illegible]
[illegible] (NAVSSI)	[illegible]
[illegible]	[illegible]

TABLE 1-SHIPBOARD INTERFACE DESCRIPTIONS

DEMANDS ON LAND ATTACK OPERATORS

It should be clear that Tomahawk has evolved to introduce new and improved capability throughout its lifetime. While these new capabilities enhance Land Attack Warfare, they also introduce greater workload and knowledge requirements on the operator. This problem is compounded by the inherent complexity of the Tomahawk Weapons System. Aside from the addition of NFCS, Tactical Tomahawk Weapons System engineering, logistics, training and installation activities are the end product of more than 90 separate government and industry organizations. While successful development of such a complex system of systems should not be minimized, it also introduces lack of uniformity for the operators that use these systems.

This is compounded by the fact that system requirements derived from the applicable system Operational Requirements Documents have placed no Human Performance requirements on system developers.

In many cases the success of the system is being carried on the backs of the operators once the system is fielded rather than integrating

the operator into the design process from the very beginning. The results subject the operator to disparate "look and feel displays" that tie operator effectiveness not just to his/her knowledge of the warfare domain but expert navigation across uncommon, disjointed Human Interfaces. Figure (4) illustrates this flaw in Land Attack today.

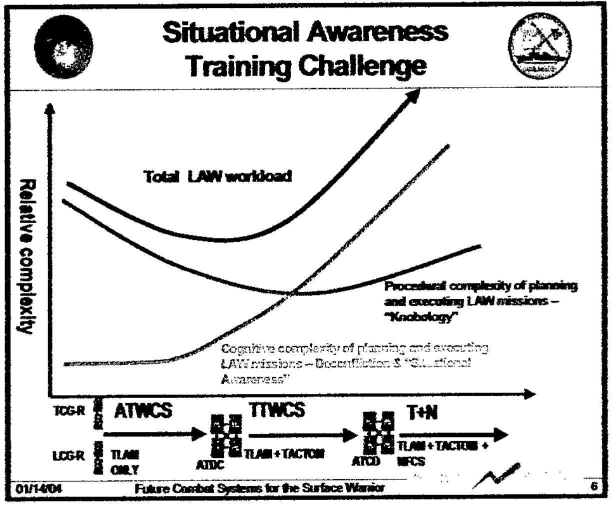


FIGURE 3- LAND ATTACK WORKLOAD

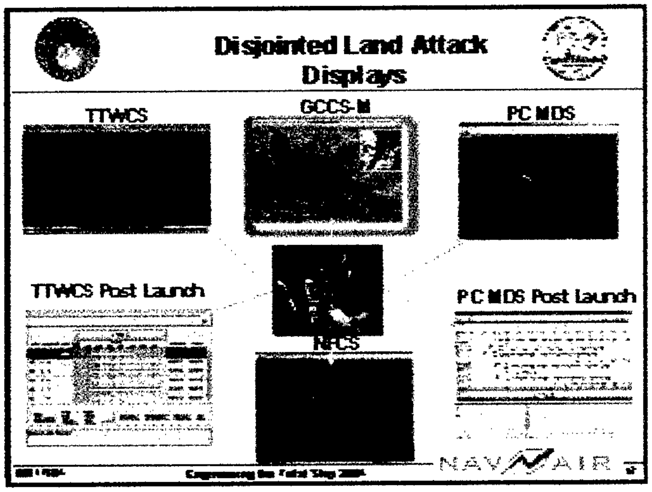


FIGURE 4-UNCOMMON DISPLAYS

TTWCS, as one component of the "Land Attack System of Systems", brings its own limitations associated with sub-optimal HCI. At its inception, TTWCS engineers attempted to place user engineering at the forefront of the design. This, however, was in direct competition with other outside influences. Savings to development costs was achieved by heavily leveraging code from ATWCS. This reuse impeded the ability to improve Human Interfaces to legacy Weapons Control System Applications. Instead, the brunt of user engineering was applied only to newly developed WCS applications. Additional restrictions imposed by use of COE and middleware requirements also influenced the final design, which contributes to the way TTWCS looks today (Figure (5)).

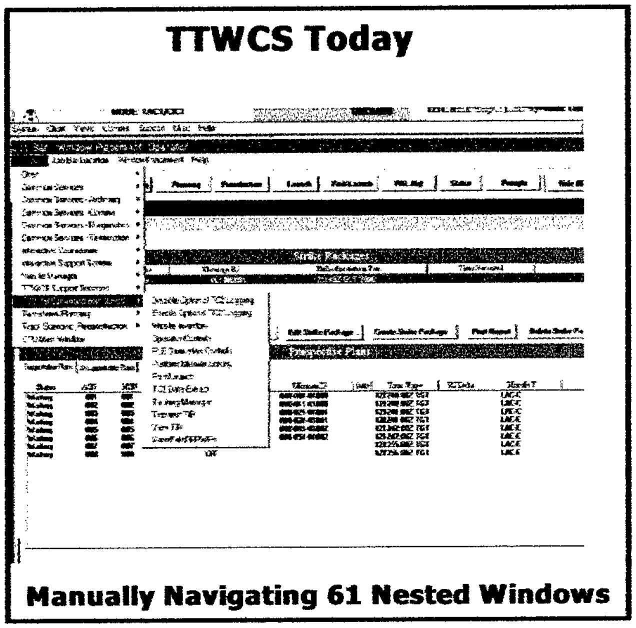


FIGURE 5- WINDOWS BASED INTERFACE

From a user engineering perspective, these displays sub-optimize the interaction between the user and the system because it forces the user to navigate through a series of nested menus and windows. Also, this windows interface does not provide the operator sufficient situational awareness to quickly assess progress executing mission critical tasks. Rather the operator must capture and synthesize information spread across multiple windows. It is this shortcoming that is at the center of future TTWCS development.

In an effort to correct this gap, the Cruise Missiles Weapons Control Program Office (PMA-282) is adopting a two- pronged strategy to improving Tomahawk Weapons Control HCI. This strategy first addresses issues

internal to Tomahawk. Fundamental to this transformation is applied emphasis on adopting "Task Centered" design. This approach equips Tomahawk operators with Tactical Decision Support, Situation Awareness displays, and intelligent automation that restrict operator's actions to those that are relevant to mission accomplishment only. The attempt is to remove unnecessary operator actions associated with manipulating window and menu schemes.

The second goal will then extend these improvements across Land Attack Combat Systems. This idea is central to eliminating the disjointed displays that confront Land Attack operators today. Applying these improvements across separate systems developed by separate organizations requires incorporating an architecture that (1) separates HCI from underlying WCS applications and (2) is extensible to other Land Attack Systems. This is in direct contrast to the way TTWCS is designed today with operator HCI directly coupled to each functional area of the WCS (see Figure (2)).

TACTICAL TOMAHAWK EVOLUTIONARY ACQUISITION STRATEGY AND ROADMAP

PMA-282 has invoked an Evolutionary Acquisition Strategy (EAS) that allows frequent opportunities to improve HCI in a series of planned system upgrades called versions. Each PMA-282 version release includes software modifications and may or may not include hardware modifications. The hardware modification(s) will be mainly driven by COTS obsolescence or an interoperability issue caused by a change in an external interface. However, it is anticipated that there will be future hardware changes linked to improved capability supporting Land Attack Warfare such as Multilevel Secure Workstations, improved watchstander consoles, replacement of Video Switching architecture with Land Attack Presentation Layer and introduction of multi-modal technology. Figure (6) depicts the PMA-282 Technology Roadmap. It should be noted that HCI improvements are at the core of future TTWCS development.

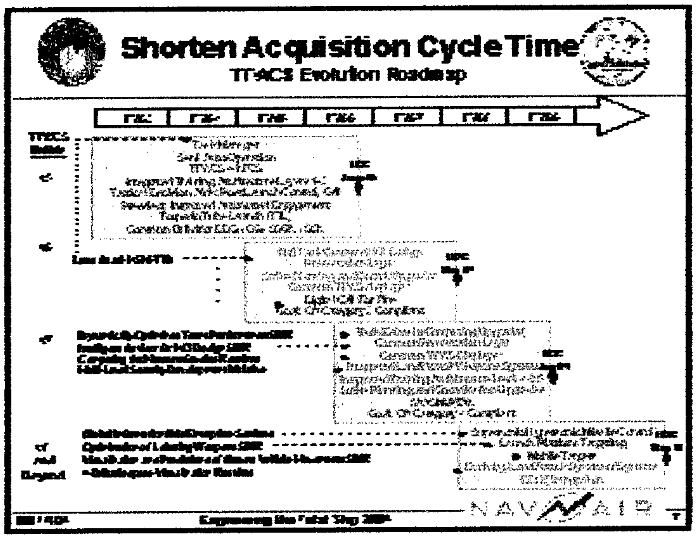


FIGURE 6- PMA-282 ROADMAP

INTIAL STEPS TOWARD TASK CENTERED LAND ATTACK HCI

PMA-282's effort to improve Tomahawk HCI has been a blend of process improvement within its own organizations and leveraging the Science and Technology efforts of outside organizations. First, the Tomahawk program has communicated to its team of system developers the priority of incorporating the end user into the System Engineering process. However, much of these process improvements are derived from a multi- year Science and Technology effort funded by ONR to develop a Task Centered Land Attack Workstation. The following section describes how this research has not only provided products but also process improvements that will be incorporated into future WCS builds.

Capitalizing on Science and Technology

In 1999, PMA-282 placed improved HCI at the center of its technology roadmap by applying seed money to further technology already funded under the Manning and Affordability Program for DD21. This research resulted in the development of a Combat System Supervisory Support (CSSS) and Multi-Modal WatchStation (MMWS) that demonstrated the viability of Task Managed HCI technologies in an Air Defense Warfare (ADW) domain by

improving performance and reducing training time. The Tomahawk program recognized the value of applying similar technology to the Land Attack Warfare (LAW) domain. By proactively investing in applying this technology to Land Attack, the Tomahawk program enjoyed a greater than full return on its original investment as this research was continued under the ownership of two Office of Naval Research Future Naval Capability projects (FNC).

The Land Attack FNC project was set up to have two critical elements. The first was development of an actual Task Centered Land Attack Interface. This interface includes decision aids that assist the operator to more efficiently execute tasks, and an HCI layer including a task manager. The HCI layer will rest on top of the applications within the system and present all information to the operator in a manner that optimizes decision-making and effectiveness. The second and most important focus area was developing the design artifacts that would allow an outside organization (such as TTWCS System developers) to incorporate this Task Centered Interface into a legacy system. In fact, these artifacts were provided to TTWCS developers as quarterly transition packages containing:

- analysis of Tomahawk tasks
- activity diagrams;
- task centered design related HCI & software requirements;
- interactive prototypes (Java and Rapid Prototype) of HCI and Decision Support.
- usability reports and focus group data
- Unified Modeling Language (UML) representations of the software design of the HCI (including decision support concepts);
- system engineering assessments to support transition of the products into the operational TTWCS system
- data dictionary
- user workflow

In addition, engineering white papers focused on particular HCI design concepts were used as a means of articulating both the concepts and the projected impact on TTWCS.

FNC Products transitioned in V5

PMA 282 expressed a desire to transition as much of the FNC project as possible into v5. To support this request, a workshop attended by members of the FNC Project team, TTWCS developers, and PMA-282 was convened in September 2002 to discuss what portions of the project could be incorporated into TTWCS v5. It was concluded that three separate products developed as part of the Land Attack Task Centered Display could be successfully transitioned within the cost and schedule constraints of v5. The first two of these included enhanced Situation Awareness Plot and improved Cell Pre-selection Decision Aids to optimize missile/mission matching.

While these products offer tremendous improvements, the crowing achievement for v5 was the early transition of a v5 Task Manager (Figure (7)). Task Manager provides revolutionary improvements to warfighter effectiveness by streamlining operator actions required to complete specific tasks. It also offers a degree of Situational Awareness unequaled with traditional windows displays. These improvements are realized by providing a front-end task oriented pane display capturing information previously spread among multiple windows. It also employs an attention management scheme useful to supervisors and operators that replaces the flood of scrolling alerts and prompts present today. The task

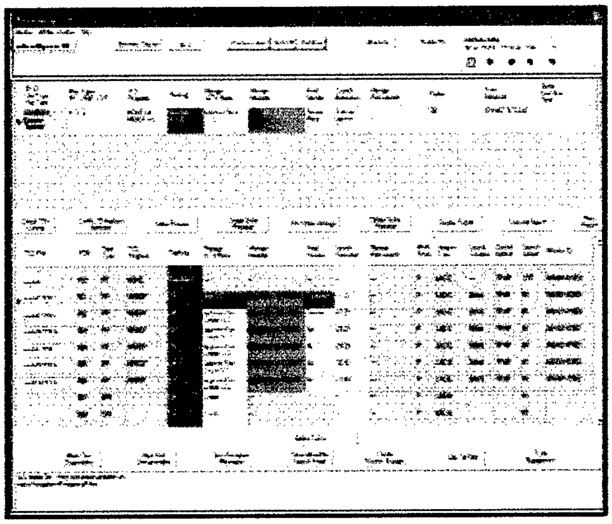


FIGURE 7- v5 TASK MANAGER

manager developed for v5 does not represent the full up version that is being developed under the research project but allows the operator to more efficiently execute tasking to engage land targets.

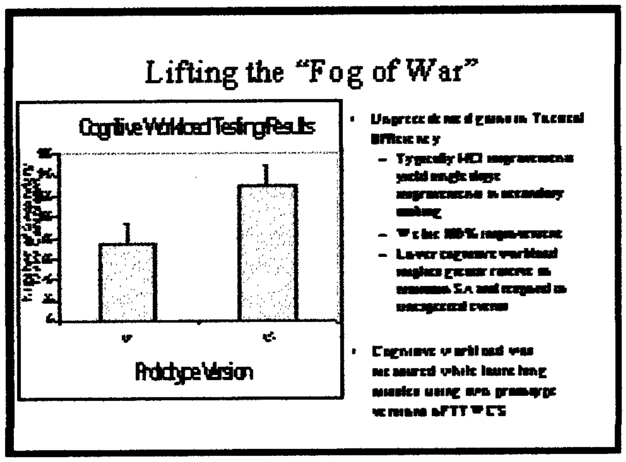
Task Manager offers such significant improvements because its display is oriented to provide both operators and supervisors clear status on progress of the current task. Major task steps associated with ESP execution are oriented across the top of the pane display. These steps are seen as individual cells that provide progress status. Status and operator intervention is communicated through the use of color, text and visual prompts. Providing progress indicators aligned in a row is consistent with a timeline orientation and is very easy to interpret. Additionally, the task manager takes Situational Awareness to new levels by providing contextual indications of workload. While progress associated with an individual Strike Package is captured in a specific row of cells, additional strike packages will receive its own row on Task Manager. This scheme alerts operators and supervisors that new Strike Tasking is literally stacking up before their eyes.

Task Manager's intuitive orientation properly focuses operators and supervisors to quickly assess task progress and workload. This is a revolutionary improvement that could not have been realized in a traditional windows environment.

Validation of v5 Task Manager

In validating the Task Manager concept, a comparative study was conducted based on usability test results from TTWCS v4 (IOC system) and v5 (utilizing v5 Task Manager). This comparative study focused on collecting human performance data and assess whether the v5 TTWCS design is a significant improvement over its v4 predecessor indicated by reducing cognitive workload, improving user performance, and increasing user satisfaction. Secondly, the goal was to collect valuable user feedback to influence the next iteration of design. Twenty-one participants from the United States Navy and two participants from the United Kingdom (UK) Royal Navy participated in the three rounds of these evaluations. During testing, participants completed the missile launch sequence from the point of receipt of electronic strike packages to the launching of all missiles. Cognitive workload was correlated with the number of secondary (unrelated) tasks the operator could successfully perform during the execution of the test scenario.

The results of the testing demonstrated that the v5 user interface (especially the Task Manager) drastically reduced user cognitive workload. These results, summarized in Figure (8), shows that the operators cognitive reserve was doubled using the v5 task manager allowing the operator to take on additional tasks. This is especially relevant considering the greater responsibilities associated with Land Attack Warfare to support Call for Fire orders, LPMP and Tomahawk missile control. Usability testing also validated significant improvement in Navigation times. Representative comments such as, "This is a gigantic improvement." and "Now anybody can quickly learn to launch Tomahawk missiles." add further evidence that the v5 design is a revolutionary improvement.



Lifting the "Fog of War"

FIGURE 8-V5 USABILITY TEST RESULTS

Other Human Engineering Process improvements incorporated into V5

Successful transition of FNC products is only part of PMA-282's effort to improve upon existing TTWCS HCI. PMA-282 and TTWCS developers are also instituting significant process improvements aimed at improving future designs. First, a User Performance Working Group was established as an arm of the System Engineering Team with a focus on

Human Engineering issues. This working group has undertaken a number of initiatives that will result in greatly improved Human Systems Integration.

Among these efforts is the creation of an HCI style guide. This style guide was created out of the recognition that there were serious disparities in GUI look and feel throughout the WCS. The HCI style guide was generated to gain consistency and adopt a common look and feel across all parts of TTWCS and eventually Land Attack Weapons Systems. It is also worth noting the User Engineers assigned to the DDX program have also collaborated in this effort as one of the first steps toward a common Land Attack Display Environment. To fully capitalize on this effort, this group has also developed an HCI Design Document for the purpose of ensuring that HCI design features are linked to system requirements or address previously cited problems.

Secondly, this group was responsible for inserting specific Human Performance metrics into the System Test Process. These additional measurements will be used to substantiate improvements in user efficiency, error rates, cognitive workload and Situational Awareness as the system evolves.

Lastly, from a process standpoint, the most pronounced distinction between v4 and v5 is the rigor assigned to the creation and application of user workflows. User workflows represent an artifact that extends the description of "what" a system will do to "how" it will do it. Specifically, the user workflows are used to describe the allocation of work between the operator and the WCS in the execution of all system tasks. These workflows were only partially developed in v4 and only applied to newly developed areas of the system. In contrast, v5 placed user workflows as the gospel for system design. These workflows were extensively scrubbed resulting in hundreds of changes aimed at gaining efficiency between user and system interaction. The priority of these documents is clear to the developers since current and future changes to user workflows require PMA-282 Program Manager approval.

BEYOND V5- DEVELOPING THE LAND ATTACK PRESENTATION LAYER

While v5 has provided an opportunity for early transition of numerous FNC products, full incorporation of Task Centered Design utilizing the remainder of FNC products is targeted for v6/v7. This is consistent with PMA-282's evolutionary approach to HCI improvements with the end goal of developing and delivering a common presentation layer spanning multiple Land Attack Combat Systems. This presentation layer is built upon three main ideas:

- Common HCI across multiple Land Attack Weapons and Command and Control Systems
- Enabled by an extensible architecture built on OA standards
- .Presentation layer interaction with Land Attack Combat Systems is Task Centered.

HCI "Presentation Layer" description

The task centered HCI layer is a principle technology product that will result from this effort, see Figure 9. The task-centered HCI is shared across the application components; a radical departure from traditional

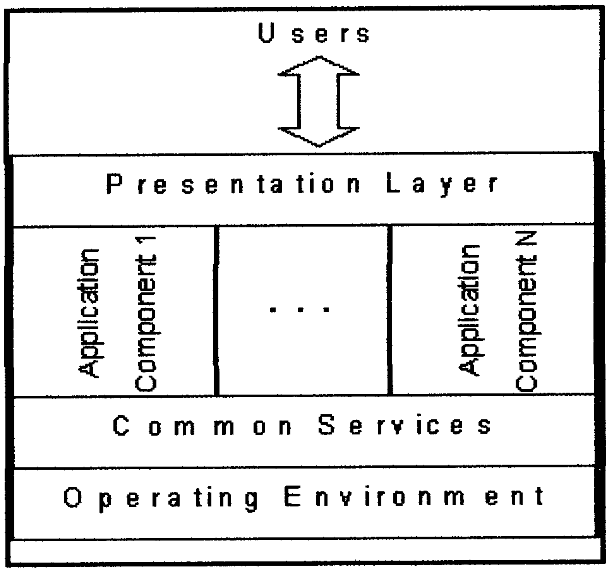


FIGURE 9- PRESENTATION LAYER

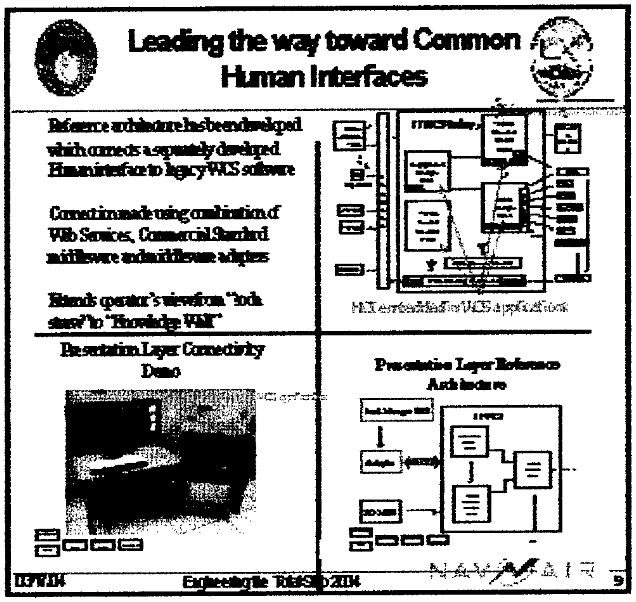
programming models and the one used by TTWCS today wherein each application provides its own HCI.

Decoupling the user interface from application logic also allows for modular insertion of emergent user interface technologies with minimal impact to underlying business logic components. Rapid integration of new technologies is supported through an open architecture user interface design. The design conforms to current computer science best practices, and is not restricted to any current commercial processor. This approach enables rapid fielding of modern technologies.

Presentation Layer Connectivity Demonstration

In FY03, Naval Surface Weapons Center, Dahlgren VA (NSWCDD) and SPAWAR Systems Center, San Diego CA (SSC-SD) developed and demonstrated a software prototype that serves as a reference implementation for the future TTWCS Presentation Layer. This reference design included not only a Java implementation of the advanced HCI but also an architecture connecting this HCI to legacy TTWCS applications. This approach was based on aggressively exploiting new web-based software technologies and required development of four software components in Java: a Connectivity Tier, a Task Management Tier, a Console Client, and a Thin Display Client. The ultimate objective of this demonstration was to illustrate that a separately developed HCI could be connected to the actual WCS and could be used to perform the seven-steps of the "Execute a Block III TLAM Pre-Planned Mission" task: review and validate tasking, plan engagements, select missiles, monitor missile preparation, perform final review of the engagement, launch missiles and report launch status.

The Connectivity Tier served as a means of connecting two diverse software environments: the advanced HCI prototype, which leveraged web services and Java-based technologies, and the tactical software applications components of TTWCS. The latter environment uses a mixture of Common Object Broker Reference Architecture (CORBA) middleware and socket-based Application Programming Interfaces (APIs) for inter-process communication. To accomplish this connectivity for one task thread required interfacing with five TTWCS software components: the Tomahawk Command & Control (TC2) Task Handler, the TC2 Mission Handler, the Engagement Manager, the Missile Manager (MM) Executive, and the MM Cell Preselection component. Figure (10) illustrates this architecture supporting an overarching Task Manager HCI and how it contrasts with the TTWCS legacy architecture, which couples HCI to functional areas of the WCS.



Leading the way toward Common Human Interfaces

Reference architecture has been developed which connects a separately developed Human interface to legacy WCS software

Connection made using combination of Web Services, Commercial Standard middleware and middleware adapters

FIGURE 10- PRESENTATION LAYER CONNECTIVITY DEMO

The Task Management Tier provided the logical rules that make the Task Manager work to enable user management of his/her tasks. The clients provided visualization of tasks, a situational awareness plot and associated display elements. The Console Client was a limited scope implementation of an advanced HCI for TTWCS that supported the "Execute a Block III TLAM Pre-Planned Mission" task. Lastly, the Thin Client was a web browser-based client used to support a Commanding Officer's tasks during conduct of the mission. The entire prototype was developed in *five* months from concept to working demonstration. This includes the system engineering, software design, implementation and testing phases.

Several lessons were learned from this effort. In view of the overall reference architecture, web services were found to provide standardized data exchanges and support data services discovery. The task management tier design was found to be extensible and reusable in other domains, i.e., it provides task management functionality that can be reused for any warfare area (or other application). This tier also supported both "thin" (simple, browser-based) and "thick" (complex) display clients. In summary, this connectivity demonstration showed that a "software adapter" can easily and quickly be constructed to integrate data from multiple software interfaces using diverse middleware connection mechanisms (CORBA and APIs).

COMPLIMENTARY EFFORTS

PMA-282 is sponsoring three Small Business Innovation Research (SBIR) projects that focus on support for HSI improvements. Anacapa Sciences (Santa Barbara, CA) is developing an Intelligent Advisor for HCI Design (IAHCID). IAHCID is an advanced HCI design tool that will provide designers rule-based advice during HCI design and critiques when design is complete. Micro Analysis & Design (Boulder, CO) is developing a Multimodal Interface Design Advisor (MIDA) that uses advanced task network modeling and leading edge workload assessment techniques as a basis for providing advice on the best modality (visual, auditory, etc.) to use in designing HCI to support tasks. Lastly, Harmonia, Inc. is developing advanced engineering tools to aid and automate portions of the HCI design and software development processes. Their work is based on an extensible Markup Language (XML)-compliant standard, the User Interface Markup Language (UIML) that can be "rendered" into a programming language such as C++ or Java. Developing HCI software in UIML provides a portable and flexible solution, achieving cost reductions above and beyond what its automation achieves.

SUMMARY

Land Attack Operators are confronted with managing multiple tasks using disparate systems with very short timelines. These demands are exasperated by tying operators success to intimate knowledge of system specific HCI rather than warfare area expertise. PMA-282 has embraced this challenge as the centerpiece of future TTWCS development. It has delivered on this challenge through a highly successful partnership with the Science and Technology community resulting in incorporation of Advanced HCI technology, funded under ONR FNC programs, two years ahead of schedule in TTWCS v5. This advanced HCI features a Task Manager which has been validated to improve operator effectiveness in the execution of Tomahawk Strikes by 100%. TTWCS System Developers have also leveraged this research to institute process improvements consistent with User Centered Design Principles. Extending these improvements to other Land Attack Systems will be facilitated by developing a system architecture which separates system HCI from system applications. This concept has been successfully prototyped as part of the ONR Research resulting in a reference implementation that will be provided to TTWCS System Developers to facilitate future system design.